IMP. BUREAU ENTOM.
11 OCT 1913

BULLETIN OF THE
U.S. DEPARTMENT OF AGRICULTURE

No. 8

Contribution from the Bureau of Entomology, L. O. Howard, Chief.
September 27, 1913.

THE WESTERN CORN ROOTWORM.

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INTRODUCTION.

The western corn rootworm (*Diabrotica longicornis* Say) derives its common name from the fact that the larva (fig. 1) was first observed attacking the roots of corn in the Middle West. Its larval habits, its life cycle, and the appearance of the adult insect (fig. 2) are all entirely different from those of the southern corn rootworm (*Diabrotica duodecimpunctata* Oliv.), though the worms themselves are exceedingly alike in appearance. In figure 1 the larva is extended at full length, as when feeding, having been drawn from living individuals.

The beetles (fig. 2) in life are about the size of the striped cucumber beetle (*Diabrotica vittata* Fab.), but smaller and less robust than the southern corn rootworm, and are entirely of a green or yellowish-green color, except the eyes, which are black. The farmer will be most likely to observe these feeding among the silk of the ears and the pollen of corn during late August and September, though the writer has seen them enter houses in the country at night, being attracted by the evening lamps. An abundance of these beetles in a cornfield should be a distinct warning that the field should not be planted to corn the following year, but that it should be devoted to wheat, oats, barley, rye, or to any crop other than corn.

FIG. 1.—The western corn rootworm (*Diabrotica longicornis*): Larva, or "worm." Much enlarged. (Original.)

FIG. 2.—The western corn rootworm: Adult, or beetle; *a*, claw of hind leg. Much enlarged. (Original.)

SEASONAL HISTORY.

The eggs (fig. 3) are minute, yellowish-white objects, having to the unaided eye much the appearance of minute grains of white sand.

They are deposited mostly in late August and in September, in shallow crevices in the ground, more often among the brace roots of the corn. These eggs hatch the following May and June, and the larvæ, always nearly white in color, attack the roots of the corn and never burrow into the lower stem as does the southern budworm. (See fig. 5.) After completing their growth the larvæ abandon the corn roots and construct earthen cells in the soil, within which they change to pupæ (fig. 4), which are white like the larvæ, and then, during late July and August, to adults or beetles. There is therefore only one generation annually. The beetles may perhaps live over winter in extreme southern Texas, but they do not do so farther north, where they are of the greatest economic importance.

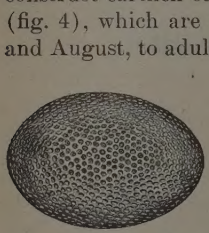

FIG. 3.—The western corn rootworm: Egg. Highly magnified. (Original.)

DISTRIBUTION.

The species occurs from Nova Scotia southward to Alabama and Mexico, westward to southern Minnesota and South Dakota, and thence south to southern New Mexico.

Curious enough, but a matter of decided economic importance, is the fact that its area of destructive abundance does not include all of the territory which it inhabits. The greatest destruction has been wrought, so far as known, in Illinois, Indiana, Ohio, Iowa, Missouri, South Dakota, Nebraska, Tennessee, and probably Kentucky.

HISTORY OF THE INSECT AND ITS RAVAGES.

FIG. 4.—The western corn rootworm: Pupa. Much enlarged. (Original.)

The beetle was described in 1823 by Mr. Thomas Say, from specimens taken by him while connected with the Maj. Long expedition to the Rocky Mountains, and its habitat was given by him as the Arkansas Territory.[1]

No facts concerning the habits of this insect were recorded until the year 1866, when specimens of the beetles were referred to Mr. B. D. Walsh by Prof. W. S. Robertson, of Kansas, who found them in large numbers on imphee or sorghum, their natural home being a large thistle. Mr. Walsh, in acknowledging the receipt of the specimens, stated that he had taken three specimens many years before on flowers in central Illinois.[2] Eight years later, in August, 1874, Mr. H. Webber, of Kirkwood, Mo., sent some larvæ and pupæ to Prof. Riley, with the complaint that the former were burrowing into the roots of his corn and doing considerable damage. In July,

[1] Journ. Acad. Nat. Sci. Phila., vol. 3, p. 460, 1823.
[2] Practical Entomologist, vol. 2, p. 10, 1866.

1878, Prof. Riley[1] again received larvæ, this time from Mr. G. Pauls, of Eureka, Mo.,[2] and from these he reared adult beetles on the 14th of the following month.

During the spring of 1874 the writer began to collect Coleoptera in the vicinity of Waterman, Dekalb County, Ill., but during this and the following two years obtained only a single beetle of this species. This single specimen, taken by the writer in the summer of 1874, was captured in a field of corn, and the failure to secure more individuals during the next two years will indicate the rarity of the insect at that time. Within seven or eight years, however, it had become so abundant throughout the neighborhood, and indeed on the same farm, then as now owned by the writer, as to render it impossible to secure more than a single full yield of corn without changing for a year to some other crop. Up to that time corn had generally been successfully grown on the same ground for a number of consecutive years. The writer's observations in Dekalb County reflect with surprising accuracy the conditions that obtained throughout the corn-growing sections of Illinois, as shown by the information brought together by Dr. S. A. Forbes, then as now State entomologist[3] of Illinois. May, 1884, the writer ceased to be connected with Dr. Forbes's office and became associated with the Division of Entomology of this department and was soon thereafter transferred from Illinois to La Fayette, Ind.

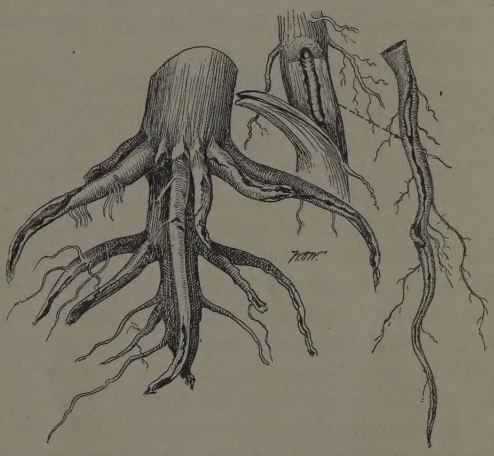

FIG. 5.—Work of the western corn rootworm in roots of corn; at right, rootworm in situ. (Original.)

The principal damage, as previously indicated, is caused by the larvæ, and since 1882, in localities where no preventive measures have been used, the damage to the corn crop has been very serious. In 1885 Mr. Moses Fowler, of La Fayette, Ind., owner of an extensive tract of land, estimated his loss during that season through the ravages of the pest at $16,000, or about 15 per cent of the entire crop. On the basis of this estimate the loss sustained in 24 of the corn-

[1] American Entomologist, vol. 3, p. 247, 1880. (Note.—See "Roots of corn injured by some unknown insect." American Entomologist, vol. 2, p. 275, 1870.)

[2] Report of the Commissioner of Agriculture for 1878, p. 208, 1879.

[3] 14th Rept. State Ent. Ill., pp. 10–31, 1883.

producing counties of that State for that one year would amount to nearly $2,000,000.[1] Although the pest is much more destructive on high or tile-drained lands, Prof. Forbes in 1886 reported serious injury to a field in southern Illinois which had been under water for three weeks during the spring.[2] There is no indication that the insect is susceptible to meteorological influences, although the effect of its ravages is aggravated by an extremely dry season. In fact, the extreme effect of the larva upon the plants is very similar to that of severe drought.

Under date of March 7, 1887, Mr. B. F. Ferris, Sunman, Ind., a close observer, communicated with the writer as follows:

> There has been for a number of years something, I know not what, working at the roots of our corn, so that in some seasons the corn does not have roots sufficient to support it, anything like a fresh breeze blowing it down, there being scarcely any brace roots.

Sunman is in southeastern Indiana, close to the White and Ohio River Valleys, which connect with the lower Big Miami Valley in western Ohio, and when the writer was transferred from Indiana to Ohio, June 1, 1891, he at once became interested in learning whether this corn rootworm had extended its depredations into the cornfields of Ohio. The first report of injuries came from Sater, Hamilton County, in the extreme southwestern part of the State, during September, 1892, the charge being that the beetles ate the silk from the ears of sweet corn before the kernels had become fertilized.

A careful survey of extreme western Ohio during the summer of 1893 revealed the beetles in cornfields throughout the country drained by tributaries of the upper Wabash River, and throughout the valley of Big Miami River, but not beyond, to the northward or eastward. A similar survey, made in the summer of 1894, revealed the pest in the region of the upper Maumee River in the northwestern part of the State and in the valley of the Little Miami River on the east. In 1895 the pest had reached the Scioto River Valley, almost if not quite halfway from east to west across the State, and from Columbus southward to the Ohio River; while in the opposite direction its range extended from Columbus more or less irregularly northwestward to the Michigan line in Fulton County. Still later it appeared farther eastward, in the upper valley of the Muskingum River. There was no guesswork in these surveys, as they were carefully made in person by the writer, who rode over the country each year when the adult insects were abroad, examining fields and noting the presence or absence of the beetles. The following year these observations were verified through larvæ found at work by the writer or observed and sent to him by farmers.[3]

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[1] Indiana Agricultural Report, p. 188, 1885.
[2] Entomologica Americana, vol. 2, p. 174, 1886.
[3] Ohio Agr. Exp. Sta., Bul. 68, pp. 39–41, maps 1–2.

It has been thus the writer's good fortune to follow personally the destructive spread (though not the actual diffusion) of the species throughout three States and from the years 1874 to 1902, both inclusive.[1]

During the years 1911 and 1912 an outbreak of this insect was studied in the Duck River Valley, middle Tennessee, by Mr. George G. Ainslie. In 1913 the same observer found the larvæ attacking corn in the bottom lands of the Tennessee River about Chattanooga, Tenn.

The pest appears to be making its way into and throughout the bottom lands of rivers flowing through the Southern Atlantic and Gulf States, precisely as it has been observed to do in Indiana and Ohio.

DIFFICULTY IN DETECTING INJURY TO CORN.

As will have been noted, the work of the larvæ is very obscure and few farmers are likely to detect them at work in the roots during June and July, while it would be simply impossible for the farmers, even if they did discover them, to connect them definitely with the little green beetles that swarm in the silk of the ears during summer and early fall.

FOOD OF THE BEETLES.

In the cornfield the food of these beetles is made up of corn silk and pollen. Rarely do they eat of the unripe kernels at the tips of the ears, and then only when birds have previously pecked into these kernels. Outside the cornfields the writer has found them in the blossoms of thistle, sunflower, goldenrod, cucurbits, cotton, clover, and rose, and on the leaves of cucumber and beans, while the species has been reported to him as eating into ripe apples where the skin had been previously ruptured by other causes. Dr. Forbes has found spores of fungi and pollen of smartweed in their stomachs. More recently Mr. George G. Ainslie has found the beetles feeding on the leaves of corn and on the pollen of the evening primrose and asters.

[1] *Changed conditions that may have caused a change of habit in the insect.*—As the writer well remembers, the principal crop in many portions of Illinois, especially throughout the prairie country, up to 1862 was spring wheat. Influences of the Civil War at that time brought the price of pork up to a point where its production became a most profitable occupation for the farmer. At the same time wheat growing declined rapidly, the acreage being devoted to corn in order to afford food for the increasing number of hogs. In those days crop rotation received scant attention from the ordinary farmer, and corn was more often than otherwise planted year after year on the same ground. How soon it was, after this change in the principal crop from wheat to corn, that these beetles, attracted to the cornfields perhaps by the enormous amount of pollen found there as well as by the equally inexhaustible food supply offered by the silk, began to deposit their eggs and develop in these fields, it is not possible to say. We do know, however, from the records already given, that injuries from the larvæ began to be noticed in 1874, about 10 or 12 years after this change in production of wheat and corn took place, thus giving us at least a clue to the primary causes which seem to have changed the food of the insect to a cultivated crop.

EFFECTS OF ATTACK OF THE LARVÆ.

The initial effect of the work of the larvæ in the roots of corn is a shortening of the ears, leaving long tips devoid of kernels. As the infestation and injury increase, plants fail to develop ears, and finally a dwarfing of the stalks occurs. The appearance of the crop is precisely the same as it would be if the land were impoverished. Indeed many farmers, ignorant of the real trouble, claim that their soil has "run out" and is incapable longer of producing corn. One farmer insisted that his corn was damaged by careless cultivation. For this reason much injury may be done by the pest before it is recognized at all.

NATURAL ENEMIES.

The Biological Survey has found specimens of *Diabrotica longicornis* in stomachs of the nighthawk (*Chordeiles virginianus*) and the wood pewee (*Myiochanes virens*).

The natural enemies of this species are exceedingly few, the principal one being the parasitic fly *Celatoria diabroticæ* Shim., figured in Bulletin 5 of this department as an enemy of the adult of the budworm. Mr. George G. Ainslie, however, has found that the beetles are attacked by the so-called chinch-bug fungus, *Sporotrichum globuliferum*. The larvæ of the click-beetle *Drasterius elegans* Fab. are also frequently found among those of this species and may destroy some of them.

CROP ROTATION AS A PREVENTIVE MEASURE.

In all of the history of this, one of the most destructive pests in the cornfield, there is not an instance on record in which corn has been injured when planted on land following a crop of small grain, such as wheat, rye, barley, or oats. Except on grounds subject to overflow, which prevents a rotation of crops so that corn is or must be grown for two or more successive years, this pest is one of the easiest to control. Two instances only need be cited in order to prove this fact.

In Dekalb County evidence of the protection afforded by the rotation of crops is afforded on a much larger scale. On a farm of 4,600 acres owned by Hon. Lewis Steward, near Plano, rotation of crops has been the regular rule; 1,600 acres of this land was planted to corn this year, and 700 acres were carefully examined by Mr. Webster. In August only 10 acres of this entire tract was found affected by the corn rootworm, and this was where, in the rearrangement of the fields, a small tract of ground happened to have been planted to corn the previous year. All about Mr. Steward's place, on farms where rotation was not systematically practiced, the damage done was serious and general.[1]

[1] Quotation from 14th Rept. State Ent. Ill., p. 29, 1885.

The second instance is that of Mr. Moses Fowler, previously mentioned on page 3. At the time referred to (1885) the Fowler estate, comprising a single tract of about 18,000 acres, near Fowler, Ind., was farmed by tenants and there were about 10,000 acres of corn growing on the premises. Some of the fields were but slightly injured and these were such as had either produced oats or grass within two or three years. Other fields were damaged from 10 to 75 per cent or more. Mr. Fowler, the following spring, directed his tenants to sow 5,000 acres of the worst infested fields to oats and the remainder of the 10,000 acres were sown to oats the second year. Thereafter no attempt was made to grow corn two successive years on the same ground, and as a result the pest was eliminated and no further damage was sustained.

What one man can do, who has control of thousands of acres, a community can also accomplish if the people combine and follow a similar course of procedure.

Dr. Forbes, in his thorough and painstaking investigations of the insect in Illinois, has found many similar instances of the efficiency of crop rotation in eliminating the insect from cornfields. These data have been supplemented by later studies of the writer and by other observations made by him extending over the same period in other States; so that there is no longer the slightest doubt of the efficiency of this measure, which is now considered essential to good farming.

POSSIBLE EXCEPTIONS TO EFFICIENCY OF CROP ROTATION.

In this period of nearly 40 years only a few possible exceptions to the effectiveness of crop rotation have come to the writer's knowledge. One of these came from a farmer in northern Illinois whom the writer knew personally and who in 1886 complained of the attack of these larvæ on his corn, which was planted on ground that had been devoted to clover and timothy the year previous. This farmer was familiar with the pest and its work and sent specimens of the larvæ. The only explanation that could be offered for this unusual injury was that the beetles forsook the cornfields after the pollen had ceased to fall from the tassels and the silk of the ears had become too dead and dry to afford them food, and that some of the females which had not already finished oviposition made their way to the clover field, fed in the blossoms, and oviposited in the soil, thus giving rise to the larvæ that the next year attacked the corn which followed the clover crop in this field.

The second complaint came from a farmer in Indiana who for two years had fed considerable corn fodder to stock in a pasture of blue grass and timothy. After plowing up this ground and planting it

to corn he reported that the crop was attacked by these worms. In this case no specimens accompanied the complaint.

It goes without saying that the beetles are found and must develop where very little corn is grown, but time has shown that there is little danger to be apprehended from these.[1]

Quite recently Mr. C. N. Ainslie, of this bureau, has found slight injury to corn in fields in Nebraska where this crop has followed small grain.

DEPREDATIONS ON LAND SUBJECT TO OVERFLOW.

The frequent submergence during fall, winter, or early spring, even for weeks at a time, of fields in which the eggs of these beetles have been deposited does not seem to affect such eggs in the least. Throughout the country north of the Ohio and Arkansas Rivers it is these low bottom lands that are kept most continuously in corn, and therefore it is here that in later years the danger from the pest is greatest. This is not, so far as now known, true of the lower Mississippi Valley, for the reason that planters there rotate with cotton, otherwise the ravages of the insect would probably be felt there as well as in the more northern States, as the writer has observed the beetles feeding on the pollen of the cotton bloom. Thus we see that throughout the country it is only where crop rotation is neglected that damage is at all to be feared.

[1] *Possible origin of a corn-feeding race.*—It will be noticed that Mr. B. D. Walsh, the first State entomologist of Illinois, found three of these beetles in central Illinois many years prior to 1866 (Practical Entomologist, vol. 2, p. 10, 1866). Mr. Ottoman Reinecke, of Buffalo, N. Y., wrote the author in 1893 that he had, prior to 1880 and for some years, collected the beetles in abundance on willow along the margin of a creek near the city during July and August; while Mr. W. H. Harrington wrote the author years ago of his finding them in Nova Scotia. Thus it is clearly shown that the eastward advance each year, as previously recorded, does not represent the real advance of the species. It represents the advance of a race that feeds on the pollen and silk of corn, some of whose larvæ develop in the roots, the adults from these spreading from field to field and under favorable conditions giving rise to myriads of worms that feed on the roots and destroy the crop. The origin of this race appears to have been the prairie country in Illinois, which in many places begins at the Mississippi River and extends into northwestern Indiana. It is true that the first reports of injury to the roots of corn by the larvæ came from Eureka and Kirkwood, Mo., both of which are near St. Louis; but just across the Mississippi River in Illinois are wide stretches of prairie country which near the river are subject to overflow.

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